# Factors Affecting Changes in Elderly Life Expectancy

**Background:** The social and economic development across various regions in China is uneven, leading to disparities in residents' health status due to differing economic levels and public health resources. Analyzing how social and economic development, medical standards, and other external factors affect life expectancy changes in these regions enhances our understanding of population aging.

**Method:** This paper used the census data, the China Statistical Yearbook, and the China Population and Employment Statistical Yearbook in 1982, 1990, 2000, 2010, and 2020. The dynamic spatial Durbin model analyzed the factors affecting the life expectancy of the elderly population.

**Results:** The elderly life expectancy in each Chinese province depends on both time and space. The spatial econometric model offers a more effective quantitative analysis of the factors influencing this life expectancy compared to traditional statistical methods. Comparing the spatial panel measurement models of different states, the dynamic spatial Durbin model is more suitable. We found that the direct effects of aging, urbanization level, education level, medical level, and economic development promote the increase of life expectancy among the elderly population in this region, while the indirect effect of urbanization level inhibits the increase of life expectancy among the elderly population in other regions.

**Key Words:** Life Expectancy; spatial dependence; spatial Durbin model; China

## 1. Introduction

The differences in social and economic development in different regions of China affect the health of residents, which is mainly reflected in the differences in economic level and public health resources. In the context of the accelerated aging of the population, it is particularly important to study the life expectancy of the elderly, which is helpful to understand the health status of the elderly, grasp the overall aging trend, and provide a basis for policy formulation and public health resource allocation.

In biomedicine, residents' health issues are influenced by personal characteristics, behaviors, social status, social structure, and environmental factors. Robert (1999) and Robert et al. (2000) found a significant positive correlation between per capita GDP and health indicators like life expectancy at lower levels of economic development. However, once economic development reaches a certain threshold (e.g., among developed countries), this correlation diminishes. Economic development enhances living conditions, social infrastructure, and public services, positively impacting residents' health. The socio-economic development of different regions of China is uneven, and the health status of residents also differs, which is affected by factors such as the level of economic development and public health resources (Qi and Niu, 2015；Yang and Wang, 2016；Zhang, 2016, Zhou et al., 2016). Taking life expectancy in 2020 as an example, some developed regions (e.g., Beijing, Shanghai, Tianjin, Zhejiang) have a life expectancy of more than 80 years, while some western regions (e.g., Tibet, Yunnan, Qinghai) have a life expectancy of less than 75 years. Existing studies have pointed out that the factors influencing the difference in life expectancy in different regions include the level of economic and social development, income disparity, urbanization, education level, and medical conditions (Cheng and Yang, 2015；Qi and Niu, 2015；Qi and Li, 2018). Cheng and Yang (2015) demonstrated that a 10% increase in urbanization rate corresponds to a 0.37% rise in average life expectancy and a 2.48% reduction in neonatal mortality rate. Notably, substantial regional disparities exist in the influence of urbanization on residents' health status. Qi and Niu (2015) established a correlation between regional economic development levels, income inequality, and the health status of local populations. When controlling for individual socioeconomic factors, higher regional economic development further enhances self-rated health. Additionally, Qi and Li (2018) confirmed that economic development level and its growth rate, income disparity, as well as the distribution of educational and healthcare resources, are critical determinants contributing to regional differences in life expectancy.

Regional differences are an important reason for the differences in life expectancy in different regions. Woods et al. (2005) confirmed the effect of geographical factors on life expectancy. Berkman et al. (2014) noted that in the United States, differences in income, gender, ethnicity, and geographic location between groups are the main causes of differences in life expectancy. Raleigh (2021) argues that population life expectancy has also changed over time, and that there are significant geographical inequalities. Zhang and Zhang (2005) believe that geographical environment and socio-economic factors are important factors affecting the difference in life expectancy. Qiu et al. (2004) found that mortality rates were relatively low in the northern, northeastern, and eastern parts of China, while higher in the southwest, especially on the Tibetan Plateau. Zhou et al. (2016) used disease burden data from various provinces in China (based on the Global Burden of Disease Study 2015) and found that the developed eastern regions of Shanghai, Beijing, Hong Kong, Macau, Zhejiang, Jiangsu, Tianjin, and Guangdong had higher life expectancies and healthy life expectancy, while the western regions of Tibet, Qinghai, Guizhou, Xinjiang, and Yunnan had lower values. Cheng and Yang (2015) verified that there are obvious regional differences in the impact of urbanization on residents' health, and the role of urbanization on residents' health in the eastern and central regions is significantly stronger than that in the western region.

The above analysis shows that there are many studies on factors affecting life expectancy in China, but the impact of economic development, urbanization level, education level, medical level, ageing population, minority level on the size and direction of life expectancy is quite controversial. In terms of methods, existing studies mostly used qualitative analysis and traditional statistical methods. The few studies employing spatial analysis mainly used spatial lag models or spatial error models to analyze cross-sectional data. Both the life expectancy itself, and the economic, social, cultural, medical, and aging population factors that affect the change in life expectancy are strongly spatially correlated. If the spatial dependence of these factors is not included in the model or included in an inappropriate model, the reliability of the results will be affected. Thus, this paper aimed to examine the impact of economic, social, cultural, medical, and aging population factors on life expectancy of 60 year-old population using the dynamic spatial Durbin model (hereafter SDM) with considering the spatial dependence of life expectancy and its influencing environmental factors, and the time-lagged life expectancy .

## 2. Methods

### 2.1 Specification of Dynamic Spatial Durbin Model

The dynamic SDM mainly comprises three components: the time-lag of dependent variables, endogenous interaction effects, and exogenous interaction effects in the model.

$$Y_t = \tau Y_{t-1} + \rho W Y_t + X_t \beta + W X_t \theta + \mu + \alpha_t + \varepsilon_t \tag{1}$$

Where $Y_t$ denotes an $N \times 1$ column vector of the dependent variable, representing 60 year-old LE in $i(i = 1, \Lambda, 31)$ province at $t(t = 1, \Lambda, t)$; $Y_{t-1}$ represents the first-order time lag of 60 year-old LE; $X_t$ represents an $N \times K$ matrix of explanatory variables; W represents the $N \times N$ non-negative spatial weight matrix, describing the spatial connectivity of each unit. $WY_t$ represents the endogenous interaction effect, referring to the mutual influence of the dependent variables of each province through the spatial weight matrix. $WX_t$ represents the exogenous interaction effect, referring to the influence of independent variables of a province on 60 year-old LE in other provinces through the spatial weight matrix. The parameters $\tau, \rho, \beta, \theta$ are coefficients of the dependent variable's first-order time lag $Y_{t-1}$, endogenous interaction effect $WY_t$, explanatory variable and exogenous interaction effect $WX_t$, respectively. $\mu$ is a $N \times 1$ vector, used to control all variables that change with the province but not with time, called spatial-specific effects; $\alpha_t$ is $N \times 1$ vector, used to control all variables that do not change with the province, but change with time, called time-specific effects. Some studies have pointed out that it is more reasonable to use fixed effect models when using complete data at the national level(Elhorst,2014). Therefore, we chose time- and spatial-specific fixed effects models. The error term, $\varepsilon_t$, is an $N \times 1$ vector, containing independent and identically distributed error terms with a mean of 0 and a variance $\sigma^2$.

2.2 Direct and Indirect Effects

Due to the endogenous interaction effect $WY_t$ of SDM, the influence of a particular explanatory variable on the dependent variable at a time of this unit will also act on the dependent variable of that unit through the endogenous interaction effect (that is, "feedback effects"), meaning $\beta$ in Equation (1) cannot truly reflect the influence of a specific explanatory variable on the dependent variable of this unit. Therefore, it is necessary to decompose the estimation results of the SDM model into direct effects and indirect effects (also called spillover effects) （Lesage and Pace, 2009;]

Fischer, 2011）.

According to Elhorst(2014), Equation (1) can be written as:

$$Y_t = (I - \rho W)^{-1} \tau Y_{t-1} + (I - \rho W)^{-1} (X_t \beta + W X_t \theta + \mu + \alpha_t + V_t) \tag{2}$$

The short-term effect of K-th explanatory variable of X in unit 1 up to unit N at time t on the dependent variable of all other units is:

$$\left[ \frac{\partial E(Y)}{\partial X_{1K}} \Lambda \frac{\partial E(Y)}{\partial X_{NK}} \right]_t = (I - \rho W)^{-1} [\beta_k I_N + \theta_K W] \tag{3}$$

Equally, the long-term effects can be given by:

$$\left[ \frac{\partial E(Y)}{\partial X_{1K}} \Lambda \frac{\partial E(Y)}{\partial X_{NK}} \right]_t = [(1-\tau) I - \rho W]^{-1} [\beta_k I_N + \theta_K W] \tag{4}$$

**3. Data and Measurement**

3.1 Data

In this paper, we adopted the data from 31 provinces in mainland China in 1982, 1990, 2000, 2010, and 2020 to examine the factors influencing the life expectancy of 60 year-old population from a spatial perspective[16-20]. Each province provides the life expectancy of 60 year-old population, the proportion of the elderly population, the level of education, and the proportion of ethnic minorities in the total population in the census data of the corresponding year. Other data were from corresponding China Statistical Yearbook[22] and China Population & Employment Statistical Yearbook[21].

3.2 Measurement

*Dependent variable*, life expectancy of the 60-year-old population, which represents the average number of years that a 60-year-old population can survive according to the mortality rate of each age in a given period.

*Economic development, GDP.* Referring to previous research (Berkman et al.,2014; Deng, 2010), we also used GDP per capita (logarithm) to represent economic development, and examined the relationship between the economic development level of a region and life expectancy of the 60-year-old population.

*Aging population, AGE*. The ageing of the population is still increasing, and many studies have shown that there are differences in the degree of ageing between different regions (Zhou et al., 2016; Li, 2017), we used the proportion of elderly population to measure the relationship between the degree of ageing and life expectancy of the 60-year-old population.

*Urbanization level, URB*. Consistent with previous research (Treme and Craig, 2013; Cheng and Yang, 2015;Van de Poel et al., 2012), we used the urbanization rate to examine the relationship between urbanization level and life expectancy of the

60-year-old population.

*Education level, EDU*. Some studies use average educational or illiteracy rate to reflect the education level in a region (Zheng, 2010; Ming and Dong, 2010; Qi and Li, 2018). We used average educational to examine the relationship between education level and life expectancy of the 60-year-old population.

*Medical level, MED*. The level of medical and health care is an important factor affecting the health of the population, improving the level of medical and health care, reducing the mortality rate of the population, and promoting the increase of life expectancy of the population (Zheng, 2010; Ming and Dong, 2010; Qi and Li, 2018). We also used health personnel per 10,000 people to represent medical level, and examined the relationship between the medical level of a region and life expectancy of the 60-year-old population.

*Minority level, MIN*. Consistent with previous research (Tu and Wang, 1995; Ming and Dong, 2010), we used the proportion of minority in the total population to examine the relationship between minority level and life expectancy of the 60-year-old population.

The definitions and descriptive statistics of variables are presented in Table 1.

Table1. Descriptive statistics for 60 year-old life expectancy and explanatory variables

| Variable | Definition | Mean | SD | Observation |
|---|---|---|---|---|
| *Dependent variable* | | | | |
| 60 year-old LE | The average number of years that a 60-year-old population can survive according to the mortality rate of each age in a given period | 18.81 | 2.105 | 155 |
| *Explanatory variable* | | | | |
| GDP | Natural log of gross domestic product per capita | 8.224 | 1.594 | 155 |
| AGE | The proportion of elderly population | 9.598 | 2.896 | 155 |
| URB | Percentage of people live in the cities or towns | 36.291 | 18.472 | 155 |
| EDU | Average educational | 8.084 | 0.824 | 155 |
| MED | Health personnel per 10,000 people | 18.429 | 12.282 | 155 |
| MIN | The proportion of minority in the total population | 14.375 | 21.352 | 155 |

Notes: 60 year-old LE denotes Life Expectancy of the 60-year-old population; AGE denotes Proportion of elderly population; GDP denotes Economic development; URB denotes Urbanization level; EDU denotes Education level; MED denotes Health personnel per 10,000 people; MIN demotes Proportion of minority population.

## 4. Results

(1) Results of OLS and Spatial Models

Table 1 shows the regression results. Firstly, in the results of the three models SEM, SAR, and SDM, the direction of the influence of five explanatory variables on 60 year-old life expectancy did not change, but the statistical significance changed. The three models are intercorrelated, in Equation (1), if $\theta = 0$, SDM could be simplified to SAR; if $\theta + \rho\beta = 0$, SDM could be simplified to SEM (Elhorst et al., 2010). Referring to the test method in Belotti et al. (2020), the results show that SDM cannot be simplified to SAR ($F = 2.35$,p=0.029) or SEM ($F = 2.86, p = 0.009$).

Seondly, the correlation between individual heterogeneity error and explanatory variables is considered. We included the square of explanatory variables in SDM, but the results were not significant (results were not given). We also compared fixed effect with random effect in SDM using the Hausman test, and the results supported the fixed effects ($\chi^2 = 69.36, p = 0.000$)(Wang, 2012).

Finally, we estimated the dynamic SDM by introducing the first-order time lag of 60 year-old life expectancy in the SDM. The time-lagged 60 year-old life expectancy was significantly positive, indicating an inertia in the change of 60 year-old life expectancy, and other potential factors also had a significant positive effect on the change of 60 year-old life expectancy. The spatial autoregressive coefficients (Rho in Table 1) show that SDM overestimated the degree of spatial dependence (Rho =0.425 in SDM vs. Rho = 0.302 in Dynamic-SDM). The reason may be that the effects of other factors not included in the model on 60 year-old life expectancy were generally classified as spatial dependence. Therefore, the following analysis was based on the results of Dynamic-SDM.

Table2 estimation of the regression of LE on OLS and spatial panel models from 1982-2020

| Variable | OLS | SEM | SAR | SDM | Dynamic-SDM |
|---|---|---|---|---|---|
| 60 year-old LE lagged in time $Y_{t-1}$ | | | | | 0.861*** |
| *Main* | | | | | |
| GDP | 0.984*** | 0.005** | 0.006** | 0.042*** | 0.046*** |
| AGE | 0.260*** | 0.142** | 0.142** | 0.175*** | 0.245*** |
| URB | 0.001 | 0.004 | 0.005 | 0.016 | 0.028 |
| EDU | 0.053*** | 0.711** | 0.711** | 0.668** | 0.713** |
| MED | 0.008 | 0.051** | 0.051*** | 0.013 | 0.056** |
| MIN | 0.013** | 0.105** | 0.105** | 0.018** | 0.093** |
| *Spatial effect* | | | | | |
| Lambda | | 0.256*** | | | |
| Rho | | | 0.311*** | 0.425** | 0.302*** |

| | | |
|---|---|---|
| W*GDP | 0.000 | 0.000 |
| W*AGE | 0.066 | 0.031 |
| W*URB | 0.012 | 0.043 |
| W*EDU | 0.823** | 0.186* |
| W*MED | 0.011* | 0.043* |
| W*MIN | 0.015 | 0.259* |

Notes: 60 year-old LE denotes Life Expectancy of the 60-year-old population; AGE denotes Proportion of elderly population; GDP denotes Economic development; URB denotes Urbanization level; EDU denotes Education level; MED denotes Health personnel per 10,000 people; MIN demotes Proportion of minority population.***p<0.01，**p<0.05，*p<0.1.

(2) Average Direct and Indirect Effects of Dynamic-SDM

Lesage and Pace(2009) pointed out that in spatial econometric models, the spatial dependence makes the coefficients of independent variables no longer appropriate for measuring the influence and statistical significance of the variable, rather, the effects of independent variables on the dependent variable should be decomposed into direct and indirect effects, and then the model could be explained. Table 2 presents the short-term and long-term direct effects, indirect effects, and total effects of Dynamic-SDM. Since the analysis was based on data observed over ten-year time intervals, the short-term effects did not differ significantly from the long-term effects. For this reason, we only explained the results based on long-term effects.

Table3 The direct, indirect, and total effects of Dynamic-SDM in the short- and long-term effects

| Variable | Short-term effects | | | Long-term effects | | |
|---|---|---|---|---|---|---|
| | Direct | Indirect | Total | Direct | Indirect | Total |
| GDP | 0.006*** | 0.001 | 0.007** | 0.009** | 0.003 | 0.012* |
| AGE | 0.248*** | 0.092*** | 0.340*** | 0.844** | -1.631* | -0.787** |
| URB | 0.439*** | -0.098* | 0.341** | 0.649** | -0.138 | 0.0.511* |
| EDU | 0.035** | 0.048* | 0.083* | 0.057* | 0.087 | 0.144 |
| MED | 0.013** | 0.074* | 0.087** | 0.089* | 0.084 | 0.173* |
| MIN | -0.322*** | 0.163 | -0.159* | -1.54 | 2.039 | 0.499 |

Notes: 60 year-old LE denotes Life Expectancy of the 60-year-old population; AGE denotes Proportion of elderly population; GDP denotes Economic development; URB denotes Urbanization level; EDU denotes Education level; MED denotes Health personnel per 10,000 people; MIN demotes Proportion of minority population.***p<0.01，**p<0.05，*p<0.1.

First, population aging degree had a significant positive direct effect and negative indirect effect. The positive direct effects indicated that the population aging degree would significantly increase 60 year-old life expectancy in this region, and this is consistent with previous studies (Liu et al., 2003; Chen and Hao, 2014).The negative indirect effect suggested that population aging degree in one region would reduce 60 year-old life expectancy in other regions, which was underexamined before.

Second, GDP had a significant positive direct effect, while the indirect effect was not significant. The positive direct effect indicated that the economic development of a region would the 60 year-old life expectancy.

Third, the urbanization level had a significantly positive direct effect, while the indirect effect was not significant. The positive direct effects indicated that the urbanization level in a region would significantly increase the 60 year-old life expectancy in this region, and this is consistent with previous studies (Liu et al., 2003; Cornelli et al., 2018).

Fourth, education level had a significant positive direct effect, while the indirect effect was not significant. The positive direct effect showed that the improvement of the education level would increase the 60 year-old life expectancy in this region.

Fifth, Health personnel per 10,000 people had a significantly positive direct effect and positive indirect effect, indicating that the Health personnel per 10,000 people of a region would increase the 60 year-old life expectancy in this region and in other regions.

Finally, proportion of minority population did not have significant direct or indirect effects on 60 year-old life expectancy.

Comparison between the direct effects, indirect effects, and total effects of the explanatory variables showed the following: for the direct effect, AGE was the largest in magnitude, followed by URB, MED, EDU, GDP. For the indirect effect, AGE had the greatest effect on 60 year-old life expectancy in the surrounding region. For the total effect, AGE, URB, MED, and GDP had a greater effect on 60 year-old life expectancy. Comparing the direct, indirect, and total effects of different variables, the increase in the economic and social development level (GDP per capita and urbanization rate) of a region would inhibit the increase in the local 60 year-old life expectancy, but it was not conducive to the governance of 60 year-old life expectancy in the surrounding regions. The improvement of people’s educational level in a region not only benefited the governance of the 60 year-old life expectancy in the region, but also had an promoted effect on the 60 year-old life expectancy in surrounding regions; and the urbanization level would only affect the local 60 year-old life expectancy.

## 5. Discussion

From the perspective of the spatial regression model, there is both temporal and spatial dependence in the life expectancy of the 60-year-old population across various provinces in China. The spatial econometric model outperforms traditional statistical methods in quantitatively analyzing the factors influencing the life expectancy of this population. Among the spatial panel econometric models of different types, the dynamic spatial panel Durbin model is the most suitable for this study.

From the perspective of the direct effects of spatial regression, population aging, urbanization, education, medical care, and economic development directly promote the increase of life expectancy of the 60-year-old population. Conversely, the direct effects of the ethnic minority population inhibit the increase of life expectancy of the 60-year-old population. Firstly, increased urbanization will raise the life expectancy of the 60-year-old population within the region. The impact of urbanization level on residents' health status has been a point of contention in some studies. One perspective is that a higher level of urbanization leads to improved medical services, better education, and increased income levels for residents, thus promoting improvements in their health status (Liu et al., 2003; Van de et al., 2012; Kim and Kim, 2016; Qin et al., 2012; Cheng and Yang, 2015). Another perspective argues that urbanization brings about environmental pollution, reduced physical activity, and a diet high in energy foods, increasing the probability of obesity and hypertension, which ultimately harms the health of residents（Monda et al，2007；Treme and Craig，2013）. Secondly, the deepening of population ageing will contribute to the increase in life expectancy for the 60-year-old population in the region. The number and proportion of elderly people in China are gradually increasing, and the mortality rate of the elderly population is gradually decreasing. As a result, life expectancy continues to increase, which exacerbates the degree of population aging(Ming and Dong, 2010). Simultaneously, China's vast territory and large population, coupled with the unbalanced development of economic development and medical technology levels in various regions, have led to obvious differences in the degree of aging between different regions, demonstrating an uneven development trend (Berkman et al., 2014; Raleigh, 2018; Sun, 2012; Cheng and Hao, 2014; Wang, 2016; Zhou et al., 2016; Li, 2017). Thirdly, higher educational attainment contributes to an increase in life expectancy for the 60-year-old population in the region. With the improvement of people's education levels, people have a deeper understanding of the factors that affect physical health, promote the formation of good living habits, and improve the life expectancy of the population(Zheng, 2010; Qi and Li, 2018). Fourthly, the improvement of medical standards will contribute to the increase in life expectancy for the 60-year-old population in the region. The improvement of medical and health conditions is conducive to reducing the mortality rate of the elderly population and improving people's health levels, thereby promoting the extension of life expectancy for the elderly population(Zheng, 2010; Ming and Dong, 2010). Finally, the higher the proportion of ethnic minorities, the lower the life expectancy of the 60-year-old population, with ethnic minority factors mainly reflecting differences in lifestyle, customs, and hygiene(Tu and Wang, 1995; Ming and Dong, 2010). Therefore, the economic development of a region promotes the improvement of the living environment of local residents, the level of medical and health services, and the increase in the life expectancy of the 60-year-old population.

From the indirect effects of spatial regression, the degree of population aging, educational attainment, and healthcare level indirectly promote an increase in the life expectancy at age 60 in surrounding areas, while the indirect effect of urbanization level suppresses the increase in life expectancy at age 60 in other regions. First, the deepening degree of population aging and improvement in healthcare levels promote an increase in life expectancy at age 60 in surrounding areas. As the number of elderly people increases, the disability rate among the elderly continues to rise. The government has successively introduced multiple policies to advance the improvement of the social pension security system, enhance healthcare levels across regions, improve public health and disease prevention systems, and reduce health disparities among different areas, aiming for more equitable access to medical resources. Second, the indirect effect of educational attainment also promotes the increase in population life expectancy in surrounding areas. However, the indirect effect of urbanization level suppresses the increase in life expectancy at age 60 in surrounding regions. Population migration or movement directions between provinces in China tend to be from economically less developed areas to more developed areas, and from rural to urban and town areas(Wang, 1993; Wang, 1997). Therefore, as the urbanization level in developed areas increases, the speed of population migration or movement between regions gradually accelerates(Ge, 2015). An increase in the urbanization level of one area will suppress the increase in life expectancy at age 60 in surrounding regions.

## 6. Conclusions

In conclusion, our findings suggest that the influence of spatial dependence should be considered when studying the changes in China's life expectancy. The changes in life expectancy are the result of the interaction of social, economic, cultural, medical, and aging population. Although China's 31 provinces have their own unique socioeconomic, cultural, medical, and population characteristics, population movements and other difficult-to-observe factors between neighboring provinces will affect the life expectancy in neighboring areas. Therefore, when governing the life expectancy, it is necessary to comprehensively consider the mutual influence of neighboring areas and formulate reasonable intervention policies through health China policy and other polices under the framework of sustainable development.

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